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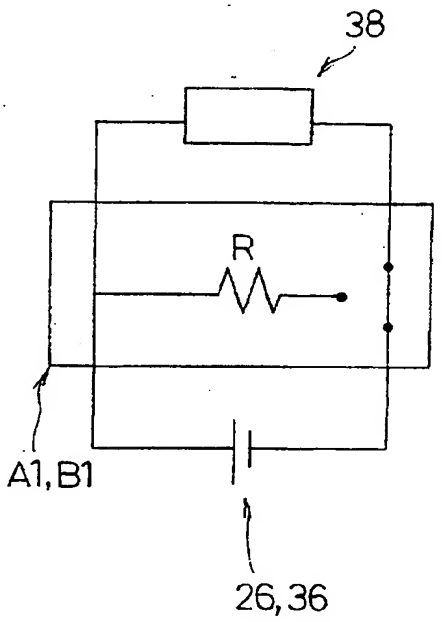
(54) Non-aqueous electrolyte rechargeable battery

(57) A non-aqueous electrolyte rechargeable battery (26) is provided with a switch element (A1) in a circuit for connecting the battery to an external power source (38), the switch element being operable in response to a change in temperature of the battery, thereby disconnecting the battery from the circuit and establishing a short circuit across the positive electrode and the negative electrode, the switch element being capable of restoring to its initial state in response to a change in temperature of the battery.

Fig. 7A



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Description

[0001] The present invention relates to a non-aqueous electrolyte rechargeable battery, and particularly to an improved safety feature provided to the battery.

[0002] Small, light-weight rechargeable batteries having high energy density are widely used as power source for portable electronic devices. While non-aqueous rechargeable batteries including lithium ion based batteries and lithium ion polymer batteries can output a high voltage, it is essential to ensure that in no circumstances should the batteries let liquid electrolyte leak and, it is desirable that the batteries maintain their high performance even under harsh conditions.

[0003] Battery characteristics may deteriorate when the battery is used under a condition exceeding an appropriate range of voltage or temperature. Also, if the battery is subjected to over-charging or left at high temperature, leakage of electrolyte may occur due to a rise in internal pressure. Accordingly, various protective devices for batteries have been proposed.

[0004] For example, Japanese Laid-open Patent Application No. 8-185849 proposes a protective device having a shape-memory alloy to shut off the electricity supply from outside of the battery upon an abnormal rise in temperature. Japanese Laid-open Patent Application No. 11-40204 teaches separation of the battery from a charging circuit upon detecting a rise in the internal pressure or temperature of the battery. It also proposes protection of battery from over-charging by the use of a varistor element that operates at a voltage exceeding a predetermined value. Japanese Laid-open Patent Application No. 10-255757 proposes a protective device having a shape-memory alloy to cause short-circuiting across the positive and negative electrodes upon detection of an abnormal rise in the temperature of the battery.

[0005] While the protective devices proposed by the above-mentioned Japanese Laid-open Patent Application No. 8-185849 and No. 11-40204 provide safety measures for preventing over-charging of the battery, the battery after the protective device has been operated is in an over-charged state. Thus there remains the risk that leakage of electrolyte may occur or that the battery characteristics may deteriorate.

[0006] The protective device disclosed in Japanese Laid-open Patent Application No. 10-255757 prevents over-charging of the battery by causing the battery to discharge, and therefore, the battery is still connected to the charging circuit after the protective device has been operated. Thus there is the risk that the battery may be further charged particularly if large current flows.

[0007] The present invention has been devised in view of the above-described problems in prior art, and it is an object of the invention to improve the reliability of non-aqueous electrolyte rechargeable batteries.

[0008] To achieve the object, a non-aqueous electrolyte rechargeable battery according to one aspect of the invention includes a switch element provided in a circuit for connecting the battery to an external power source. The switch element is operable in response to a change in temperature of the battery, thereby disconnecting the battery from the circuit and establishing a short circuit across the positive electrode and the negative electrode, the switch element being capable of restoring to its initial state in response to a change in temperature of the battery.

[0009] A non-aqueous electrolyte rechargeable battery according to another aspect of the invention includes a closure assembly for closing the open top end of a battery case that is electrically connected to the electrode of first polarity. The closure assembly includes an external terminal, an internal terminal electrically connected to the electrode of second polarity, a switch element in electrical contact with both of the external terminal and the internal terminal, and a ring-like conductive element electrically connected to the battery case and electrically insulated from both of the external terminal and the internal terminal. The switch element disconnects itself from the external terminal and makes electrical contact with the ring-like conductive element in response to a change in temperature of the battery, thereby breaking electrical connection between the battery and an external power source and establishing a short circuit to cause the battery to discharge, the switch element being capable of restoring to its initial state in response to a change in temperature of the battery, thereby re-establishing electrical connection between the battery and the external power source.

[0010] Preferred embodiments of the present invention will be hereinafter described with reference to the accompanying drawings, in which:

Figure 1 is a schematic top plan view of a battery according to one embodiment of the present invention before a switch element is mounted thereto;
Figure 2 is a schematic cross-sectional view of the battery;
Figure 3 is a perspective view of the battery with a switch element mounted thereto;
Figure 4 is a schematic cross-sectional view of a switch element provided in the battery;
Figure 5 is a vertical cross-sectional view of a battery according to another embodiment of the present invention;
Figure 6 is a cross-sectional view of a switch element provided in the battery; and
Figures 7A and 7B are schematic circuit diagrams, respectively showing an initial state of the switch element

same time causes the battery to discharge.

[0020] Instead of providing the switch element A1 on the bag 21 on the side where the input/output terminals are drawn out, it may be located anywhere at which it is connected to the circuit across the battery 26 and an external power source and to the discharging circuit, and at which it can detect the battery temperature. The temperature-sensitive element 1 may of course be provided on the side of the negative electrode. The shape memory alloy employed for the temperature-sensitive element 1 in this embodiment restores to its initial shape at a temperature around 25°C. It should go without saying that the temperature range of the shape memory alloy is not limited to the example given above, but may be set as required in accordance with battery size, performance, and the range of temperatures at which the battery is used.

[0021] As described above, should the battery be subjected to excessive charging, the charging is made to stop in response to a rise in temperature of the battery, and at the same time the battery is made to discharge. Because of the restorable characteristic of the shape-memory alloy, the switch element A1 permits itself to be repeatedly used, thus allowing the battery to be reused.

[0022] Figure 5 is a vertical cross-sectional view of a lithium ion rechargeable battery according to another embodiment of the present invention.

[0023] The positive electrode 28 is composed of a collector made of aluminum foil and a positive electrode active material layer formed on both surfaces of the collector. The active material for the positive electrode is prepared in the form of a paste obtained by mixing $LiCoO_2$, acetylene black as a conductive material, and polytetrafluoroethylene as a binder in an aqueous solution of carboxy methyl cellulose. The paste thus obtained is applied onto the collector and dried.

[0024] The negative electrode 29 is composed of a collector made of copper foil and a negative electrode active material layer formed on both surfaces of the collector. The active material for the negative electrode is prepared in the form of a paste obtained by mixing mesophase microspherical powder particles graphitized at high temperature of 2800°C, and styrenebutadiene rubber in an aqueous solution of carboxy methyl cellulose. The paste thus obtained is applied onto the collector and dried.

[0025] The positive electrode 28 and the negative electrode 29 are superposed with a polyethylene-based porous film 30 interposed therebetween, and wound around to constitute an electrode group, which is then accommodated in an aluminum-made battery case 10. A switch element B1 is incorporated in a closure assembly 37 for sealing the battery case 10. A positive electrode lead 31 of aluminum is drawn out from the positive electrode 28 such as to make electrical contact with the battery case 10, while a negative electrode lead 32 of copper is drawn out from the negative electrode 29 and electrically connected to the switch element B1.

[0026] For the electrolyte, 1.5 mol/l of $LiPF_6$ dissolved in a mixed solution of ethylene carbonate (EC), diethyl carbonate (DEC) and methyl propionate (MP) in the volume ratio of 30:50:20 was employed.

[0027] The switch element B1 includes, as shown in Figure 6, an external terminal cover 4 made of metal that serves as an external terminal of the negative electrode, an internal terminal cover 6 made of metal to which the negative electrode lead 32 is connected, a gasket 7 made of insulating material, a metal ring 5, an insulating plate 8, and a temperature-sensitive element 9 composed of shape-memory alloy, which is initially contacted to both of the external terminal cover 4 and the internal terminal cover 6, thereby electrically connecting the two. The internal terminal cover 6 makes partial contact with the temperature-sensitive element 9, and part thereof which is not in electrical contact with the temperature-sensitive element 9 is covered by an insulating member 11. The structure of the external terminal cover 4 and the internal terminal cover 6 may be interchanged. The gasket 7 is arranged surrounding the outer periphery of the external terminal cover 4, the insulating plate 8, the temperature-sensitive element 9, and the internal terminal cover 6. The ring 5 is arranged at the outer periphery of the gasket 7.

[0028] The ring 5 is electrically connected to the battery case 10, and has a projection 12 extending inwards on an inner side thereof. The projection 12 of the ring 5 extends inwards through a hole 13 formed in the gasket 7, and sits on the insulating member 11 at an inner side of the gasket 7.

[0029] The temperature-sensitive element 9 is interposed between the internal terminal cover 6 and the insulating plate 8, being electrically connected to both of the internal terminal cover 6 and the external terminal cover 4 as mentioned above. The shape-memory alloy forming the temperature-sensitive element 9 deforms when the battery temperature exceeds 60°C, detaching from the external terminal cover 4 and making contact with the protrusion 12 of the ring 5 through a resistor R placed thereon. Thus the battery is separated from the external power source and discharged through a short circuit established by the temperature-sensitive element 9.

[0030] The shape-memory alloy restores to its initial shape at around 25°C, but the temperature range of the shape-memory alloy may be set as required depending on the size and performance of the battery. The switch may be located anywhere at which it is connected to the circuit across the battery 36 and an external power source, and at which it can sense the battery temperature.

[0031] Figure 7A and Figure 7B are schematic diagrams of the charge/discharge circuit of the above-described batteries 26, 36 according to the invention, given in explanation of the mechanism how the switch element A1 or B1

[0038] As can be seen from Table 2, the batteries provided with the switch elements according to the invention exhibited superior high-temperature storage characteristics.

[0039] The temperature-sensitive element of the switch element of the invention should not be limited to the shape-memory alloy as has been described above, but may be any member that can operate in response to a change in temperature.

Claims

1. A non-aqueous electrolyte rechargeable battery, comprising:

   an element for electromotive force (18) including a positive electrode (15) and a negative electrode (16);
   a battery case (21) for accommodating the element for electromotive force therein; and
   a switch element (A1) attached to the battery case and interposed in a circuit for connecting the battery to an external power source, the switch element being operable in response to a change in temperature of the battery, thereby disconnecting the battery from the circuit and establishing a short circuit across the positive electrode and the negative electrode, the switch element being capable of restoring to its initial state in response to a change in temperature of the battery.

2. The non-aqueous electrolyte rechargeable battery according to Claim 1, wherein the switch element includes

   a temperature-sensitive element (1);
   a first conductive plate (3a) connected to one of the positive electrode and the negative electrode and disposed on one side of the temperature-sensitive element; and
   a second conductive plate (3b) connected to the other one of the positive electrode and the negative electrode disposed on the other side of the temperature-sensitive element opposite from the first conductive plate, wherein
   the temperature-sensitive element is in contact with either one of the first conductive plate and the second conductive plate, and deforms to contact the other one of the first conductive plate and the second conductive plate in response to a change in temperature of the battery.

3. The non-aqueous electrolyte rechargeable battery according to Claim 2 wherein the temperature-sensitive element is made of shape-memory alloy.

4. A non-aqueous electrolyte rechargeable battery comprising:

   an element for electromotive force including an electrode of first polarity (28) and an electrode of second polarity (29);
   a battery case (10) having an open top end for accommodating the element for electromotive force, and being electrically connected to the electrode of first polarity; and
   a closure assembly (37) for closing the open top end of the battery case, including an external terminal (4), an internal terminal (6) electrically connected to the electrode of second polarity, a switch element (9) in electrical contact with both of the external terminal and the internal terminal, and a ring-like conductive element (5) electrically connected to the battery case and electrically insulated from both of the external terminal and the internal terminal, wherein
   the switch element (9) disconnects itself from the external terminal and makes electrical contact with the ring-like conductive element (5) in response to a change in temperature of the battery, thereby breaking electrical connection between the battery and an external power source and establishing a short circuit to cause the battery to discharge, and wherein the switch element restores to its initial state in response to a change in temperature of the battery, thereby re-establishing electrical connection between the battery and the external power source.

5. The non-aqueous electrolyte rechargeable battery according to Claim 4, wherein the electrical insulation between the ring-like conductive element (5) and the external terminal (4) and the internal terminal (6) is effected by a ring-like gasket (7) disposed on an inner peripheral side of the ring-like conductive element, the external terminal and the internal terminal being arranged on an inner side of the ring-like gasket, the ring-like conductive element having an inwardly extending protrusion (12) passing through a hole (13) formed in the ring-like gasket towards between the external terminal and the internal terminal.

Fig. 1

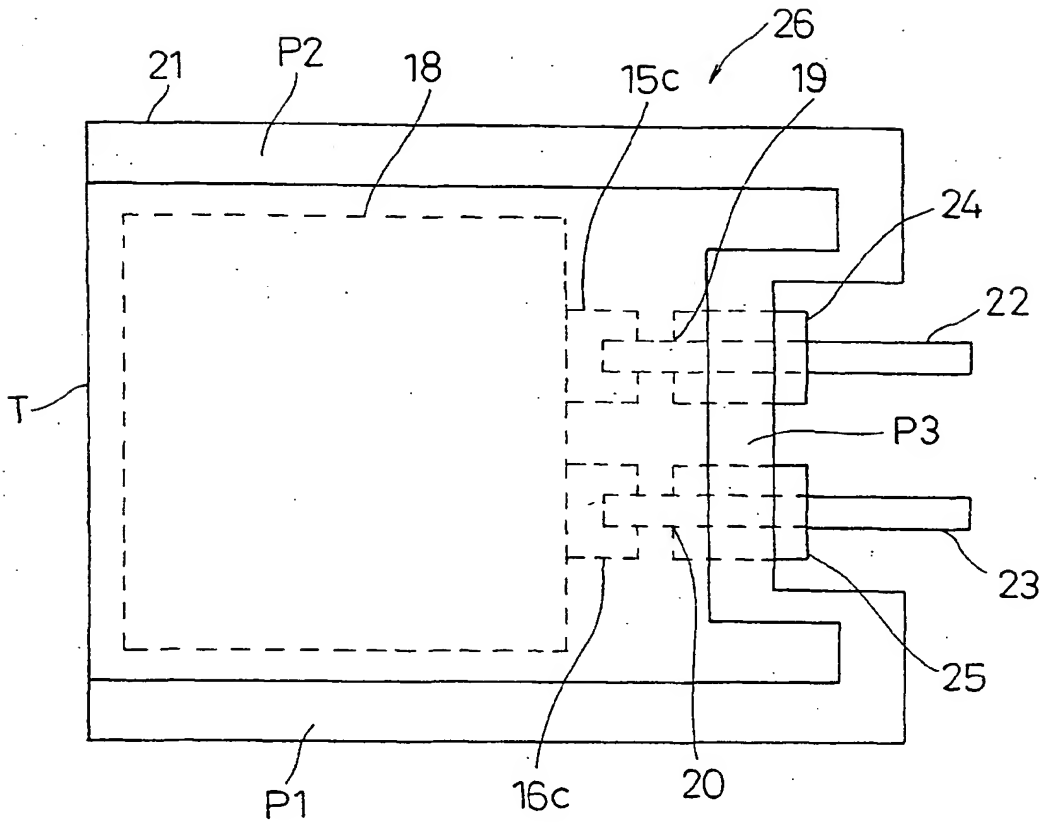

Fig. 2

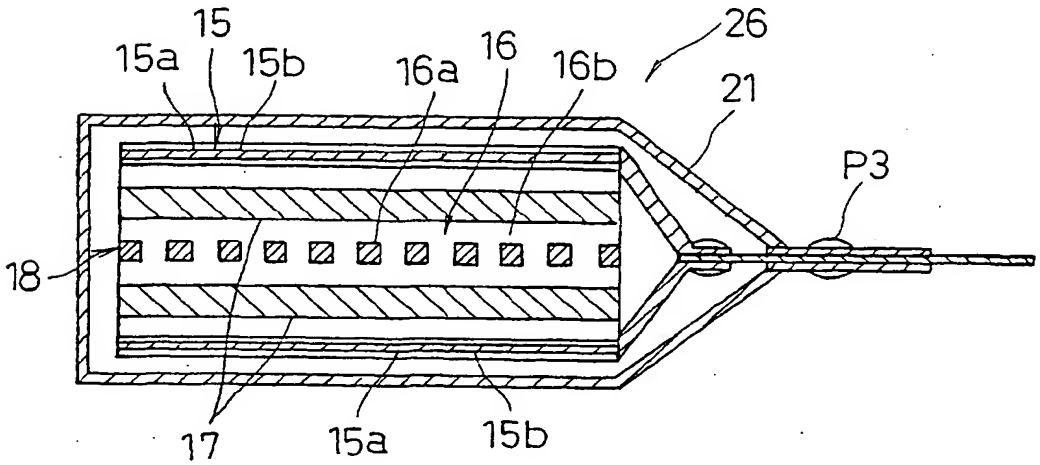

Fig. 5

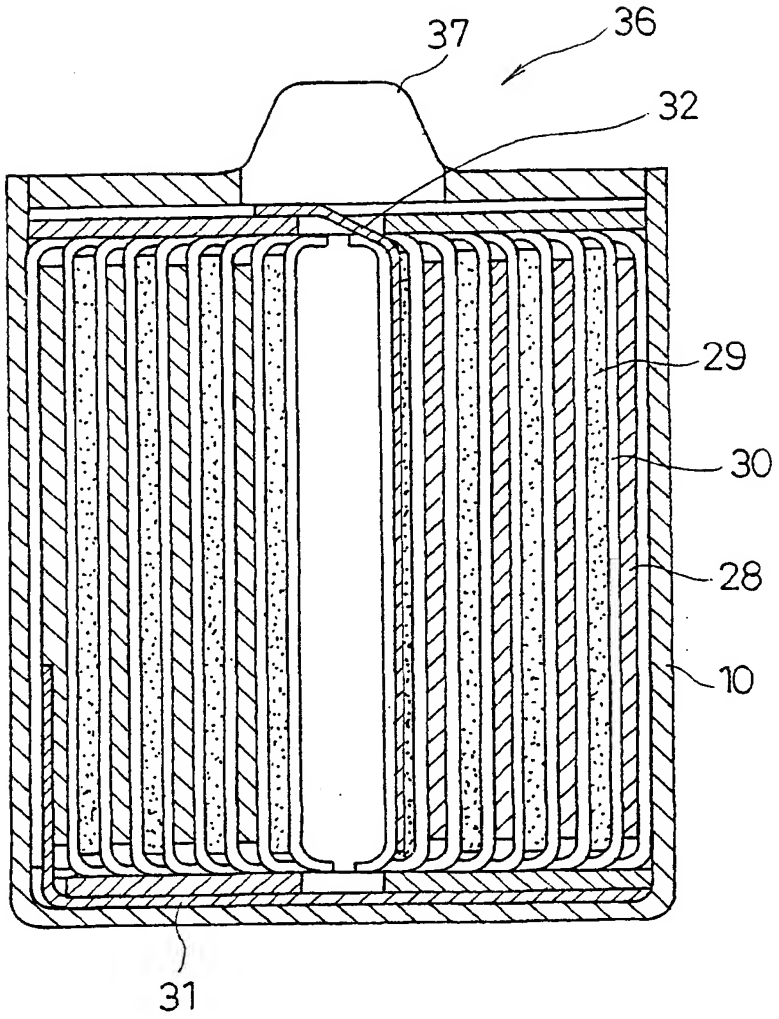

Fig. 7A

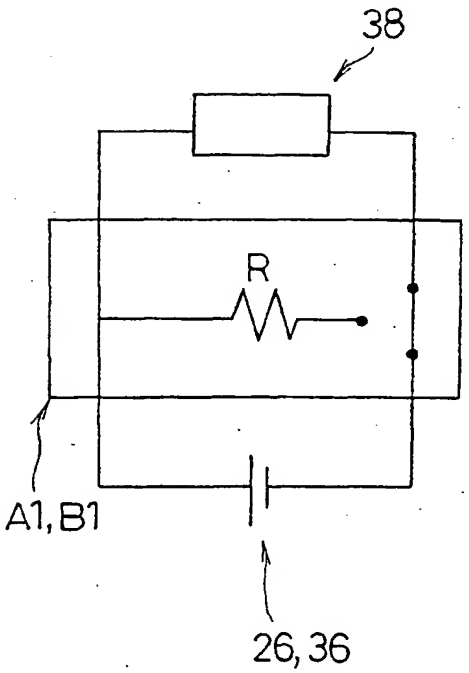

Fig. 7B

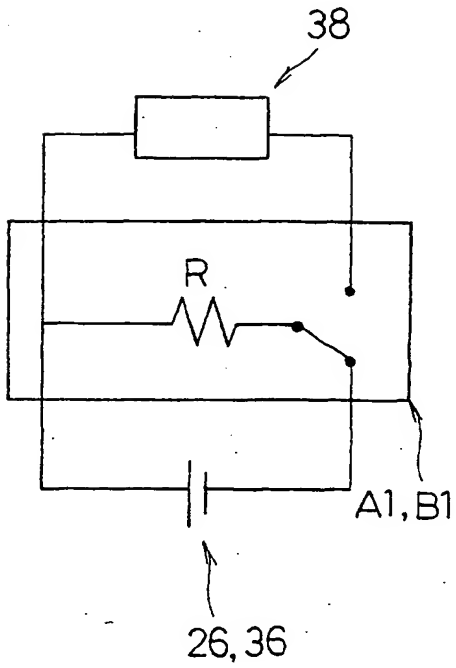

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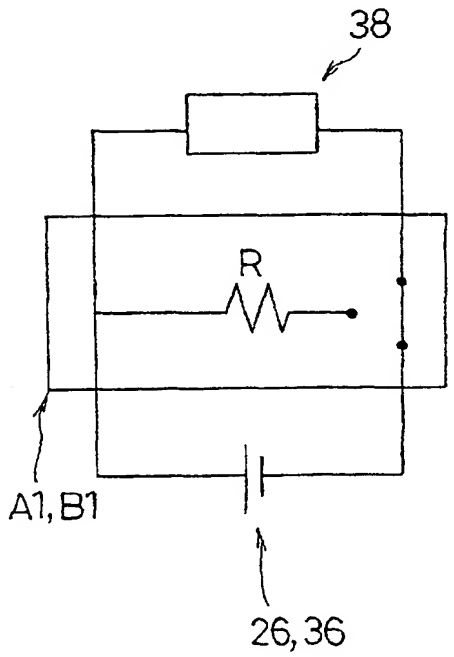
Fig. 7A



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EUROPEAN SEARCH REPORT

Application Number
EP 01 30 3158

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 0 926 796 A (HITACHI LTD, TOKYO, JP) 30 June 1999 (1999-06-30) * page 3, line 11 - line 28 * * page 14, line 6 - line 53 * * figures 15,16 *	1	H01M2/34 H01H37/32 H01H37/52
A		2-4,7	
A	EP 0 875 913 A (EMERSON ELECTRIC CO, ST. LOUIS, US) 4 November 1998 (1998-11-04) * the whole document *	1-7	
A	US 4 679 023 A (NELSON MARVIN D., ST. LOUIS PARK, US) 7 July 1987 (1987-07-07) * the whole document *	1-4,7	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

H01M
H01H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 May 2003	Peis, S

CATEGORY OF CITED DOCUMENTS

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